(51) International Patent Classification⁷: H04N 7/24, 7/52

(21) International Application Number:
PCT/IB2003/003864

(22) International Filing Date:
1 September 2003 (01.09.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/408,956   6 September 2002 (06.09.2002)   US
60/462,776   14 April 2003 (14.04.2003)   US

(71) Applicant (for all designated States except US): KONIN-
KLIJKE PHILIPS ELECTRONICS N.V. [NL/NL];
Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors; and
(75) Inventors/Applicants (for US only): GADDAM, Vas-
santh R. [US/US]; P.O. Box 3001, Briarcliff Manor, NY
10510-8001 (US). BIRRU, Dagnachew [US/US]; P.O.
Box 3001, Briarcliff Manor, NY 10510-8001 (US).

(74) Common Representative: KONINKLIJKE PHILIPS
ELECTRONICS N.V.; c/o Waxler, Aaron, P.O. Box
3001, Briarcliff Manor, NY 10510-8001 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD,
SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US,
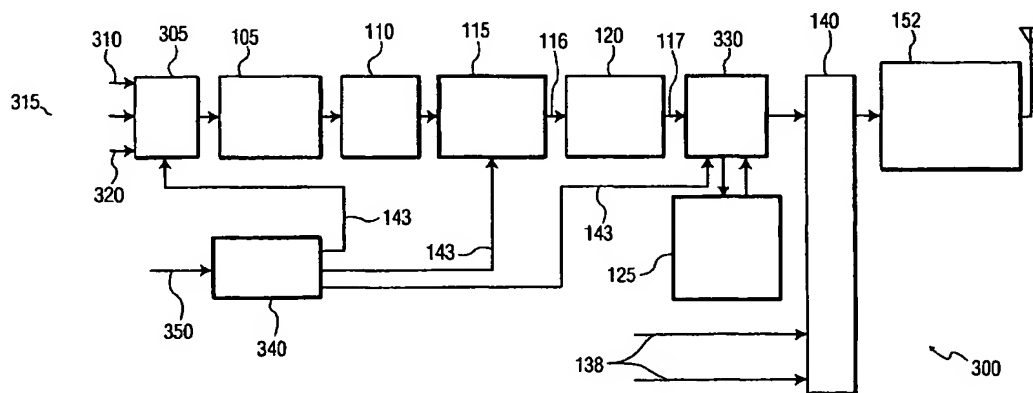UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO,
SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report
— before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: PACKET INSERTION MECHANISM FOR AN IMPROVED ATSC DTV SYSTEM

(57) Abstract: A packet insertion mechanism at the front end of a time-synchronized digital television transmission system mul-
tiplexes, along with standard packets, packets whose payload is to be transmitted with redundancy for added robustness. The mul-
tiplexer also inputs placeholder packets to accommodate duplicated content of the robust packets. Multiplexing of the robust and
placeholder packets is configured to alternate and to interleave with the multiplexing of standard packets. The distribution of the
robust packets within a frame is determined by the number of robust packets.

WO 2004/023818 A1

PACKET INSERTION MECHANISM FOR AN IMPROVED ATSC DTV SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

5   The present invention claims the benefit of

commonly-owned, co-pending U.S. Provisional Patent

Application Serial No. 60/408,956 filed Sep. 6, 2002.

10   BACKGROUND OF THE INVENTION

Field of the Invention

        The present invention relates to a digital signal

transmission system and particularly to multiplexing

different types of data, one type replacing another in the

15   multiplexed stream after the multiplexing.

DISCUSSION OF THE PRIOR ART

        The ATSC standard for digital television (DTV)

transmission over terrestrial broadcast channels uses a

20   signal that comprises a sequence of twelve (12) independent

time-multiplexed trellis-coded data streams modulated as an

eight (8) level vestigial sideband (VSB) symbol stream with

a rate of 10.76 MHz. This signal is converted to a six (6)

MHz frequency band that corresponds to a standard VHF or

25   UHF terrestrial television channel, over which the signal

is broadcast at a data rate of 19.39 million bits per

second (Mbps). Details regarding the (ATSC) Digital

Television Standard and the latest revision A/53 are

available at http://www.atsc.org/.

FIG. 1 is a block diagram generally illustrating an
exemplary prior art digital television (DTV) transmitter
5   100. MPEG compatible data packets are first randomized in a
data randomizer 105 and each packet is encoded for forward
error correction (FEC) by a Reed Solomon (RS) encoder unit
110. A/53 provides that each packet inputted at the system
front end corresponds to a segment in a 312-segment field,
10 sometimes referred to hereinafter as a "data field" or
"MPEG field." Two fields comprise a frame, each field
representing one half of the interlaced video signal
received for transmission by the system. After receipt
from the encoder unit 110, the data packets in successive
15 segments of each data field are then interleaved by data
interleaver 120, and the interleaved data packets are then
further interleaved and encoded by trellis encoder unit
130. Trellis encoder unit 130 produces a stream of data
symbols having three (3) bits each. One of the three bits
20 is pre-coded and the other two bits are produced by a four
(4) state trellis encoder. The three (3) bits are then
mapped to an 8-level symbol.

As known, a prior art trellis encoder unit 130
25 comprises twelve (12) parallel trellis encoder and pre-
coder units to provide twelve interleaved coded data
sequences. In multiplexer 140 the symbols of each trellis
encoder unit are combined with "segment sync" and "field
sync" synchronization bit sequences 150 from a
30 synchronization unit (not shown). A small in-phase pilot
signal is then inserted by pilot insertion unit 160 and
optionally pre-equalized by filter device 165. The symbol

stream is then subjected to vestigial sideband (VSB)
suppressed carrier modulation by VSB modulator 170. The
symbol stream is then finally up-converted to a radio
frequency by radio frequency (RF) converter 180.

5

FIG. 2 is a block diagram illustrating an exemplary
prior art digital television (DTV) receiver 200. The
received RF signal is down-converted to an intermediate
frequency (IF) by tuner 210. The signal is then filtered

10   and converted to digital form by IF filter and detector
220. The detected signal is then in the form of a stream of
data symbols that each signify a level in an eight (8)
level constellation. The signal is then provided to NTSC
rejection filter 230 and to synchronization unit 240. Then

15   the signal is filtered in NTSC rejection filter 230 and
subjected to equalization and phase tracking by equalizer
and phase tracker 250. The recovered encoded data symbols
are then subjected to trellis decoding by trellis decoder
unit 260. The decoded data symbols are then further de-

20   interleaved by data de-interleaver 270. The data symbols
are then subjected to Reed Solomon decoding by Reed Solomon
decoder 280. This recovers the MPEG compatible data packets
transmitted by transmitter 100.

25   While the existing ATSC 8-VSB A/53 digital television
standard is sufficiently capable of transmitting signals
that overcome numerous channel impairments such as ghosts,
noise bursts, signal fades and interferences in a
terrestrial setting, receiving antennas have increasingly

30   been placed indoors, adding to the challenge of delivering
a clear signal. There accordingly exists a need for

flexibility in the ATSC standard so that streams of varying priority and data rates may be accommodated.

5   To address these concerns, the present inventors have disclosed an enhancement to the A/53 transmitter that is backward compatible with existing ATSC receivers in commonly-assigned U.S. Patent Publication 2002/0194570, (hereinafter "the '570 application"), the disclosure of which is incorporated by reference as if fully set forth
10   herein.

     As described in the '570 application, the present inventors have provided, in an ATSC digital transmission system, a technique for transmitting a new robust bit-
15   stream along with the standard ATSC bit-stream. The threshold of visibility (TOV), i.e., a predetermined acceptable number of packet errors per second at the receiver, for the new bit-stream is typically reached at a lower signal-to-noise ratio (SNR) compared to the standard
20   ATSC stream, so that new bit-stream can be used for transmitting high priority information bits. The inventive ATSC digital transmission system and methodology is backward compatible with existing digital receiver devices.

25   As the '570 application further discusses, the MPEG data packets of the robust stream have an error correction capability greater than that of the standard stream, with both types of packets being multiplexed at the transmitter front end for concurrent transmission. The
30   order in which they are multiplexed affects the integrity of the resulting wireless signal that arrives at the receiver.

The present application expands on preferred
5   multiplexing techniques for implementation at the enhanced
A/53 transmitter front end.

SUMMARY OF THE INVENTION
10

In one aspect, the present invention is directed to a
packet insertion mechanism at the front end of an ATSC
Digital Television transmitter and methods utilized in the
inventive packet insertion.
15

In a further aspect, the present invention relates to
preferred orderings by which packets are multiplexed at the
front end of an A/53 transmitter for compatibility with the
operations of components in A/53 receivers.
20

In yet another aspect, the present invention concerns
preferred packet multiplexing orderings at the front end of
an A/53 transmitter enhanced for backward compatibility
with existing receivers.
25

In accordance with the preferred embodiments of the
invention, there is provided a digital transmission
apparatus, and method performed by the apparatus, that
improves upon the ATSC A/53 DTV signal transmission
30   standard and includes a multiplexer having an output port,
an input port for inputting an information bit-stream and
an input port for inputting a placeholder bit-stream. The

multiplexer multiplexes the bit-streams inputted from the
input ports to form a multiplexed bit-stream for output on
the output port. The transmission system further includes
a data formatter for receiving the multiplexed bit-stream
5   and for replacing bits of the placeholder bit-stream within
the received multiplexed bit-stream with bits derived from
the information bit-stream within the received multiplexed
bit-stream to form a modified bit-stream. An encoder
encodes the modified bit-stream to produce an encoded bit-
10 stream, which a transmitter transmits.

BRIEF DESCRIPTION OF THE DRAWINGS

15   Details of the invention disclosed herein shall be
described below, with the aid of the figures listed below,
in which same or similar components are denoted by the same
reference numbers over the several views:

20   FIG. 1 illustrates a block diagram of an exemplary
digital television (DTV) transmitter according to the prior
art;

         FIG. 2 illustrates a block diagram of an exemplary
25 digital television (DTV) receiver according to the prior
art;

         FIG. 3 is a top-level diagram of an embodiment
exemplary of the improved ATSC standard according to the
30 present invention; and

FIG. 4 is a flow diagram representative of methods
utilized according to the present invention.

5 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

FIG. 3 is a top-level diagram of an embodiment 300 of
the improved ATSC standard according to the present
invention.

10   The improved ATSC digital signal transmission
standard according to a first embodiment includes a packet
multiplexer or packet "mux" 305 for selecting among
inputted 188-byte MPEG compatible data packets. The mux
305 has a standard input 310 for standard packets of which

15 the standard ATSC bit-stream is comprised. The standard
packets, after transmission from the back end of the system
300, are received by existing A/53 receivers and new
receivers. A robust input 315 receives robust packets
which make up the new robust bit-stream. The robust

20 packets are received, after transmission from the back end,
by the new receiver disclosed in commonly owned, co-pending
U.S. Patent Application Publication No. US 2002/0191712
(hereinafter "the '712 application") entitled PACKET
IDENTIFICATION MECHANISM AT THE TRANSMITTER AND RECEIVER

25 FOR AN ENHANCED ATSC 8-VSB SYSTEM, the whole contents and
disclosure of which is incorporated by reference as if
fully set forth herein. Existing receivers decode the
signal that was generated at the transmitter based on the
robust packets but either ignore them or process them as

30 errors, depending on backward compatibility as discussed in
more detail further below. Multiplexing of these two types
of packets, standard and robust, at the front end of the

transmission system is disclosed by the current inventors
in the '570 application, which as mentioned above is fully
incorporated by reference herein.

5   A third type of packet, the placeholder packet,
is received over the placeholder input 320 and preferably
consists of all null values. The existing ATSC standard
accommodates null packets, for example as a means by which
to resolve clocking frequencies of connecting components
10   within the transmission system. In an aspect of the
present invention, the placeholder packets inputted at the
front end are overwritten with data subsequently generated
or derived based on the contents of inputted robust
packets.
15

           The improved ATSC transmission system 300 further
includes the data randomizer element 105 for receiving the
multiplexed output of the packet mux 305 and for first
changing the input data byte value according to a known
20   pattern of pseudo-random number generation. According to
the ATSC standard, for example, the data randomizer XORs
all the incoming data bytes with a 16-bit maximum length
pseudo random binary sequence (PRBS) which is initialized
at the beginning of a data field.
25

           The output randomized data is then input to the
Reed Solomon (RS) encoder element 110 which operates on a
data block size of 187 bytes, and adds twenty (20) RS
parity bytes for error correction to result in a RS block
30   size total of 207 bytes transmitted per data segment.

After the RS encoding, the 207 byte data segment
is then input to a new block 115 comprising a robust
interleaver, packet formatter and packet multiplexer
elements for further processing/reformatting the robust
5   input bytes. Operation of the individual elements of the
packet formatter block is described in greater detail in
commonly owned, co-pending U.S. Patent Application
Publication No. US 2002/0181581 (hereinafter "the 581
application") entitled IMPROVED ATSC DIGITAL TELEVISION
10   SYSTEM.

Most generally, the robust interleaver, packet
formatter and packet multiplexer elements for reformatting
incoming bytes are responsive to a mode signal 143 which
15   indicates whether the incoming byte is processed (for
robust bytes) or not (for normal bytes). After interleaving
robust packets in the robust interleaver, the data bytes
belonging to the incoming robust bit-stream are buffered
and grouped in the packet formatter device into groups of a
20   pre-defined number of bytes, e.g., 207 bytes. In general,
for robust packets, only 4 bits of each byte at the packet
formatter output, the LSBs (6, 4, 2, 0), correspond to the
incoming stream. The other 4 bits of each byte, the MSBs
(7, 5, 3, 1), may be set to any value for reasons as will
25   be explained in greater detail herein. After byte re-
formatting in the packet formatter 115, the bytes belonging
to robust packets are multiplexed with the bytes belonging
to the standard stream.

30   The multiplexed stream 116 of robust and standard
bytes are next input to the convolutional interleaver
mechanism 120 where data packets in successive segments of

each data field are further interleaved for scrambling the
sequential order of the data stream according to the ATSC
A/53 standard. As explained in greater detail in the '570
application, bytes associated with each robust packet or

5   standard packet are tracked in concurrent processing
control blocks (not shown).

The interleaved, RS-encoded and formatted data
bytes 117, i.e., the output of the "data formatter" which

10   includes modules 105 through 120, are then trellis coded by
a novel trellis encoder device 330. Trellis encoder unit
330 is particularly responsive to the mode signal 143 and
cooperatively interacts with a backwards compatibility
parity-byte generator element 125, herein referred to as a

15   backward compatibility (optional RS encoder) block 125, in
the manner explained in greater detail in the '570
application to produce an output trellis encoded output
stream of data symbols having three (3) bits each mapped to
an 8-level symbol. The trellis encoded output symbols are

20   then transmitted to multiplexer unit 140 where they are
combined with the "segment sync" and "field sync"
synchronization bit sequences 138 from a synchronization
unit (not shown).

25   The system 300 further includes a backend
processor 152 that incorporates the pilot insertion 160,
VSB modulator 170 and RF Up-Converter 180 of the prior art
as illustrated in FIG. 1. Accordingly, a pilot signal is
inserted into the output signal of the mux 140. The symbol

30   stream is then subjected to vestigial sideband (VSB)
suppressed carrier modulation and the symbol stream is then
finally up-converted to a radio frequency.

Also included in the system 300 is a control unit
340 that operates in accordance with the embodiment of FIG.
3 of the '712 application and the embodiment depicted in
5   FIGs. 5 through 7 in the '570 application. The control
unit 340 of the present invention has two new
modifications. First, the mode signal 143, which has a
value of either "normal" or "robust," is fed to the packet
mux 305 newly-disclosed herein. Second, the set of
10 parameters for input to the control unit 340 on input line
350 has been revised.

Output communicated by the control unit 340 with
the various modules of system 300 is not limited to the
15 connections shown in FIG. 3. The mux 305, for example,
receives from the control unit 340 a mode selection bit
which, in combination with the mode signal, determines
which of the three inputs 310, 315, 320 are selected. As a
further example, the packet formatter and the trellis
20 encoder 330 both likewise receive from the control unit 340
a mode bit, which in addition to the mode signal 143
defines the system parameter MODE. Also, as will be clear
from the discussion below, the packet formatter 115
requires the other three system parameters NRS, NRP and TR
25 as well, and inputs them from the control unit 340.

The system parameters MODE, NRS, NRP and TR
determine the number and position of robust packets in an
MPEG field. The term "robust packets" as used hereinafter
30 in the context of front end multiplexer input will refer to
either placeholder packets or "robust information packets,"
i.e. what have up until now been termed "robust packets."

Therefore, the number of robust packets multiplexed by the
packet mux 305 is equal to the sum of the number of robust
information packets multiplexed and the number of
placeholder packets multiplexed.

5

The system parameters, MODE, NRS, NRP and TR, can
be modified once every two fields, i.e. once per frame.

The MODE parameter is defined below in TABLE 1:

10

Table 1: Description of the MODE parameter

MODE	Description
00	Standard. No robust packets in the field
01	H-VSB mode
10	E-VSB mode
11	Pseudo 2-VSB mode

Mode 0 denotes the processing of standard
packets. The existing A/53 standard outputs an 8-level
15   symbol for every two bits, i.e., three bits for two bits,
or so-called "2/3 trellis coding." During mode 0, the
other three system parameters NRS, NRP, TR are not
utilized, and can be ignored. Details regarding trellis
coding for the various modes in TABLE I are further
20   disclosed in the '570 and '581 applications.

For, H-VSB (hierarchical vestigial sideband)
mode, mode 1, corresponding bits of a robust information
packet and of an embedded packet are placed side-by-side
25   and fed as a pair to a pair of input terminals to the
trellis encoder 330. An embedded packet is a constituent
of an embedded bit-stream, which is a low-priority stream
inputted in place of the placeholder bit-stream on input
320 of the packet mux 305. Accordingly, the LSBs (6, 4, 2,

0) are transferred or derived from the embedded byte, i.e.
a byte from an embedded packet, and the MSBs (7, 5, 3, 1)
are derived from the robust bytes of robust information
packets.   The symbol outputted by the trellis encoder 330

5   has 6 levels that, due to the increased spread between the
lower magnitude levels, provide greater robustness than do
the standard 8 levels.

Enhanced vestigial sideband (E-VSB) mode, mode 2,

10 yields an 8-level symbol for every information bit.
Redundancy in conveying the bit makes its transmission more
robust, in exchange for a lower information output rate.

Pseudo 2-VSB mode or simply "2-VSB mode," by

15 contrast, outputs a 4-level symbol for every information
bit, for greater redundancy and robustness than in
transmission of standard packets.

TABLE 2 below describes the NRS parameter:

20

Table 2: Description of the NRS parameter

NRS	Description
0	Backward Compatible Parity Byte Generator (BCPBG) is not used
1	Backward Compatible Parity Byte Generator (BCPBG) is used

In accordance with the present invention,

25 existing receivers will deliver to the recipient only that
information conveyed by standard packets.   New receivers,
by contrast, will receive and decode signals representative
of robust information encoded in modes 2 or 3, and
optionally in mode 1 if the signal is being received with

sufficient integrity. New receivers will also receive and
decode the standard bit-stream as an "additional bit-
stream" for subsequent decoding.

5   If NRS = 0, backward compatibility is not being
furnished by the generator 125, and the existing receiver
therefore rejects as erroneous all incoming robust packets,
i.e., signaling decoded into robust packets. Before
rejecting, however, the receiver attempts forward error
10   correction, a capability afforded by both the RS and the
trellis encoding. This wasted effort by the conventional
receiver is relieved if the robust packets are processed
for backward compatibility, i.e., when NRS is set equal to
1, since, in that case, the receiver ignores the robust
15   packet instead of recognizing it as an error.

          The TR parameter is discussed below in
conjunction with TABLE 3:

20   **Table 3: Description of the TR parameter**

TR	Description
0	Rate-1/2 coding system
1	Rate-1/4 coding system

          For standard packets, two bits are encoded to
produce one symbol, as mentioned above. When TR = 0, the
25   coding rate is "1/2" and one bit is encoded per symbol.
Ordinarily, for example, the coding rate is "1/2" for
pseudo 2-VSB mode. By contrast, when TR = 1, the coding
rate is "1/4" which means that one bit is encoded to
produce two coding symbols. Therefore, for example, each
30   symbol selected by the trellis encoder 330 operating in

mode = 11 and TR = 1 may be duplicated, with both symbols
being transmitted.

The NRP parameter is a code that specifies the
number of robust information packets N_{RI} per frame, the
number being determined from TABLE 4 below.

Table 4: Description of the NRP parameter

NRP	Number of robust packets before encoding			
	NRS = 0, TR = 0	NRS = 1, TR = 0	NRS = 0, TR = 1	NRS = 1, TR = 1
0000	0	0	0	0
0001	2	4	1	2
0010	3	8	Not defined	4
0011	4	12	2	6
0100	6	16	3	8
0101	8	20	4	10
0110	12	24	6	12
0111	16	28	8	14
1000	20	32	10	16
1001	26	40	13	20
1010	32	52	16	26
1011	39	64	18	32
1100	52	72	26	36
1101	78	76	39	38
1110	104	96	52	48
1111	156	120	78	60

The number of robust packets N_R can be determined
from the value of N_{RI} read from TABLE 4 by the following
formulas (1) to (4):

When TR = 0, NRS = 0, N_R = 2 * N_{RI} (1)

When TR = 0, NRS = 1, N_R = (9/4) * N_{RI} (2)

When TR = 1, NRS = 0, N_R = 4 * N_{RI} (3)

When TR = 1, NRS = 1, N_R = (9/2) * N_{RI} (4)

where the number of placeholder packets

$N_{PH} = N_R - N_{RI}$, as explained more fully

below.

5   Generally speaking, robust packets are
distributed uniformly in an MPEG field. One constraint is
that the maximum distance between any two robust packets is
no more than 4 packets.   In other words, over a
predetermined number of packets in the field, counting from
10   the first packet to the last robust packet, no more than 3
standard packets are to be multiplexed by the packet mux
305 consecutively. Since, as mentioned, the embedded bit-
stream at the system 300 front end replaces the placeholder
bit-stream when an embedded stream is used, the description
15   will hereinafter refer to placeholder packets with the
understanding that either placeholder or embedded packets
are implied.

Uniform distribution of the robust packets at the
20   front end is desirable for the following reasons. The
fewer levels of the robust signal make it easier for the
equalizer in the receiver to converge, by resolving
multipath or otherwise correctly determining signal values.
If, however, the supply of robust signals is not
25   continuous, i.e. is irregularly spaced in time, this
advantage at the receiver is lost. On the other hand, long
sequences of one type, i.e., all robust or all standard,
create complications for the automatic gain control (AGC)
in the receiver. Accordingly, robust packets are
30   interleaved with the standard packets uniformly.

The distance d_R between any two consecutive robust packets in a field is given by equation (5):

$$d_R = \min(\text{floor}(N/N_R), 4) \qquad\qquad (5)$$

5   where floor is a function that

truncates the fraction and leaves the

integer value, N is the total number of

packets in a field, 312, and N_R, as

mentioned above, is the number of

10   robust packets

Although a maximum value of 4 for d_R has empirically been found to be suitable, other maximum values may be used.

15

Another limitation in configuring the packet ordering is that the first packet of a field is always a robust packet if NRP > 0. The packet mux 305, in selecting among the standard, robust and placeholder inputs 310, 315,

20   320, can switch among the sources once per packet.

Packet Insertion when NRS = 0 and TR = 0

Operating under these parameters, the packet formatter 115 duplicates the bits of each robust

25   information packet to form two packets. Accordingly, each robust information packet received at the packet mux 305 is followed by a placeholder packet, which is overwritten to accommodate the increased number of bits, i.e., the original bits plus the duplicate or derived bits.

30

FIG. 4 is a flow chart showing one example of a digital signal transmission method in accordance with the

present invention for the case where NRS = 0, TR = 0. The
bit-streams are multiplexed from the standard, robust and
placeholder inputs 310, 315, 320 (step 410). If MODE = 0
(step 420), indicating a standard packet, a replacing step

5   to be described is bypassed. If MODE = 1 (step 430),
indicating utilization of embedded packets, corresponding
bits of a robust information packet and an embedded packet
are placed side-by-side (step 440), as shown in FIG. 9(a)
of the '570 application. If, on the other hand, MODE = 2

10   or 3, each bit of the robust information packet is
duplicated in a replacing step(step 450). The duplicated
or derived bit is disposed to follow the bit from which
derivation has occurred, as shown in FIG. 8(a) of the '570
application. After the bit manipulation or its bypassing

15   has occurred in forming a modified bit-stream, the modified
bit-stream is inputted two bits at a time to the trellis
encoder 330 (step 460) and the encoded stream is
transmitted (step 470).

     Steps 420 to 450 are performed by the data

20   formatter (modules 105 to 120 in FIG. 3). Accordingly, in
a preferred embodiment of the invention as shown in FIG. 3,
other steps precede and follow the bit manipulation steps
440, 450 as disclosed hereinabove.

     Referring again to TABLE 4 for another example of

25   its utilization, if NRP = 0110 and MODE = 11, each MPEG
field will have 12 robust information packets and 12
placeholder packets, as well as (312-24) = 288 standard
packets. The spacing between two successive robust
packets, as calculated from equation (5) is d_R =

30   min(floor(312/24),4) = 4. The robust packets are therefore
distributed uniformly with a distance of 4 packets between

any two successive robust packets, as demonstrated below in
TABLE 5:

**Table 5 : Packet insertion mechanism at the Randomizer input for NRS = 0
(example 1)**

Packet #	Packet type	Packet #	Packet type
0	Robust Info	92	Place Holder
1	Standard	93	Standard
2	Standard	94	Standard
3	Standard	95	Standard
4	Place Holder	96	Standard
5	Standard	97	Standard
6	Standard	98	Standard
7	Standard	99	Standard
8	Robust Info	100	Standard
9	Standard	...	...
10	Standard	304	Standard
...	...	305	Standard
86	Standard	306	Standard
87	Standard	307	Standard
88	Robust Info	308	Standard
89	Standard	309	Standard
90	Standard	310	Standard
91	Standard	311	Standard

In another example, if NRP = 110 and MODE = 11,
each MPEG field will have 52 robust information packets, 52
placeholder packets and (312-104) = 208 standard packets.
The spacing between successive robust packets is then d_R =
min(floor(312/104),4) = 3, as can be seen from TABLE 6
below:

**Table 6: Packet insertion mechanism at the Randomizer input for NRS = 0 (example
2)**

Packet #	Packet type	Packet #	Packet type
0	Robust Info	92	Standard
1	Standard	93	Place Holder
2	Standard	94	Standard
3	Place Holder	95	Standard
4	Standard	96	Robust Info
5	Standard	97	Standard

6	Robust Info	98	Standard
7	Standard	99	Place Holder
8	Standard	100	Standard
9	Place Holder	...	...
10	Standard	304	Standard
...	...	305	Standard
86	Standard	306	Robust Info
87	Place Holder	307	Standard
88	Standard	308	Standard
89	Standard	309	Place Holder
90	Robust Info	310	Standard
91	Standard	311	Standard

Packet Insertion when NRS = 1 and TR = 0

5   In this modality, the packet formatter 115 adds
        23 additional bytes to each output robust packet to satisfy
        backward compatibility requirements. The 207 bytes of a
        robust information packet are accordingly converted into
        2*207 + 2*23 = 460 bytes by the packet formatter 115. To
        accommodate this data, the packet formatter 115 converts
10   each 4 robust information packets into 9 robust packets, by
        utilizing 5 placeholder packets. To avoid additional
        overhead, the number of robust information packets per
        field is preferably limited to a multiple of 4.

15   An ordering for robust information packets in
        relation to placeholder packets, and ignoring for the
        moment the standard packets, is shown below in TABLE 7:

Table 7: Ordering in a group of 9 robust packets

Robust Packet #	Packet type
0	Robust Info
1	Place Holder
2	Robust Info
3	Place Holder
4	Robust Info

5	Place Holder
6	Robust Info
7	Place Holder
8	Place Holder

This pattern repeats for every 9 robust packets.
By successive alternating by type, instead of clustering
consecutively by type, the robust information and
5   placeholder packets are ordered to avoid delay in
subsequent transmission of the information signal. That
is, the packet formatter 115 utilizes three packets at
output to carry the complete content of one robust
information packet, and therefore preferably receives a
10   steady supply of placeholder packets, as more fully
described in the '570 application in conjunction with FIG.
10.

In a first example for NRP = 1000, MODE = 11,
15   each MPEG field has 32 robust information packets, 40
placeholder packets and (312 - 72) = 240 standard packets.
The spacing between robust packets is therefore d_R =
min(floor(312/72),4) = 4, as illustrated below in TABLE 8:

20   **Table 8: Packet insertion mechanism at the Randomizer input for NRS = 1 (example 1)**

Packet #	Packet type	Packet #	Packet type	Packet #	Packet type
0	Robust Info	18	Standard	36	Robust Info
1	Standard	19	Standard	37	Standard
2	Standard	20	Place Holder	38	Standard
3	Standard	21	Standard	...	...
4	Place Holder	22	Standard	280	Place Holder
5	Standard	23	Standard	281	Standard
6	Standard	24	Robust Info	282	Standard
7	Standard	25	Standard	283	Standard

8	Robust Info	26	Standard	284	Place Holder
9	Standard	27	Standard	285	Standard
10	Standard	28	Place Holder	286	Standard
11	Standard	29	Standard	...	...
12	Place Holder	30	Standard	306	Standard
13	Standard	31	Standard	307	Standard
14	Standard	32	Place Holder	308	Standard
15	Standard	33	Standard	309	Standard
16	Robust Info	34	Standard	310	Standard
17	Standard	35	Standard	311	Standard

In a second example, with NRP = 1011, MODE =11, each MPEG field has 64 robust information packets, 80 placeholder packets and (312 – 144) = 168 standard packets. The robust packet spacing is therefore d_R = min(floor(312/144),4) = 2, as shown below in TABLE 9:

Table 9 : Packet insertion mechanism at the Randomizer input for NRS = 1 (example 2)

Packet #	Packet type	Packet #	Packet type	Packet #	Packet type
0	Robust Info	18	Robust Info	36	Robust Info
1	Standard	19	Standard	37	Standard
2	Place Holder	20	Place Holder	38	Place Holder
3	Standard	21	Standard	...	...
4	Robust Info	22	Robust Info	280	Place Holder
5	Standard	23	Standard	281	Standard
6	Place Holder	24	Place Holder	282	Robust Info
7	Standard	25	Standard	283	Standard
8	Robust Info	26	Robust Info	284	Place Holder
9	Standard	27	Standard	285	Standard
10	Place Holder	28	Place Holder	286	Place Holder
11	Standard	29	Standard	287	Standard
12	Robust Info	30	Robust Info	288	Standard
13	Standard	31	Standard	...	...
14	Place Holder	32	Place Holder	308	Standard

15	Standard	33	Standard	309	Standard
16	Place Holder	34	Place Holder	. 310	Standard
17	Standard	35	Standard	311	Standard

Packet Insertion when TR = 1

5   As indicated in TABLE 4, the number of robust information packets when TR = 1 is equal to half that when TR = 0; yet, the number of robust packets remains the same. The packet insertion accordingly is as indicated in TABLES 5 through 9, except that every other robust information

10   packet is replaced by a placeholder packet.

       While there have been shown and described what are considered to be preferred embodiments of the invention, it will, of course, be understood that various

15   modifications and changes in form or detail could readily be made without departing from the spirit of the invention. It is therefore intended that the invention be not limited to the exact forms described and illustrated, but should be constructed to cover all modifications that may fall within

20   the scope of the appended claims.

25

CLAIMS:

1. A digital signal transmission apparatus comprising:

a multiplexer (305) having an output port, an input port (315) for inputting an information bit-stream and an input port (320) for inputting a placeholder bit-stream, for multiplexing the bit-streams inputted from the input ports to form a multiplexed bit-stream (410) for output on the output port;

a data formatter (105 – 120) for receiving the multiplexed bit-stream and for replacing bits of said placeholder bit-stream within the received multiplexed bit-stream with bits derived from said information bit-stream within said received multiplexed bit-stream to form a modified bit-stream (117);

an encoder (125, 138, 140, 330) for encoding the modified bit-stream to produce an encoded bit-stream (460); and

a transmitter (152) for transmitting the encoded bit-stream (470).

2. The apparatus of claim 1, wherein the deriving creates a new bit, but retains any bit from which derivation has occurred (450).

3. The apparatus of claim 2, wherein said replacing comprises duplicating bits of said information bit-stream within said received multiplexed bit-stream to form duplicate bits and substituting the duplicate bits to replace bits of said placeholder bit-stream within said received multiplexed bit-stream (115, 450).

4. The apparatus of claim 1, wherein the multiplexer is configured to multiplex an additional bit-stream (310) in forming said multiplexed bit-stream, the data formatter is configured to bypass (420) said replacing when operating on said additional bit-stream within said received multiplexed bit-stream to form said modified bit-stream, and the encoder is configured to process every bit of said modified bit-stream when operating on bits derived from said additional bit-stream and to process every other bit of said modified bit-stream when operating on bits derived from said information bit-stream (330, 460).

5. The apparatus of claim 1, wherin the multiplexer is configured with an additional input port (310) for inputting an additional bit-stream.

6. The apparatus of claim 5, the multiplexer being configured to input a plurality of additional bit-streams, a plurality of information bit-streams and a plurality of placeholder bit-streams through their respective input ports (310 - 320) for said multiplexing to form said multiplexed bit-stream (410), each of the information bit-streams to be multiplexed by the multiplexer having an identical number of bits, each of the placeholder bit-streams to be multiplexed by the multiplexer having an identical number of bits, the multiplexer being configured to multiplex each of the information and placeholder bit-streams for their respective identical number of bits before selecting another bit-stream for multiplexing (305).

7.   The apparatus of claim 6, wherein said
multiplexer (305) is further configured to perform said
multiplexing so as to select in succession, over a
predetermined number of bit-streams, no more than three of
said additional bit-streams.

8.   The apparatus of claim 6 wherein said
multiplexer (305) is further configured to perform said
multiplexing so as to input in succession one or more of
the additional bit-streams (310) after each input of one of
an information bit-stream (315) and a placeholder bit-
stream (320).

9.   The apparatus of claim 8, wherein the plural
bit-streams (310 - 320) are identical in length, and the
inputting of one of an information bit-stream and a
placeholder bit-stream successively alternates, over at
least most inputs of the one information or placeholder
bit-stream, between an information bit-stream and a
placeholder bit-stream.

10.   The apparatus of claim 1, wherein said
replacing comprises removing selected bits from said
information bit-stream within said received multiplexed
bit-stream and substituting the removed bits to replace
bits of said placeholder bit-stream within said received
multiplexed bit-stream (450).

11.   A digital signal transmission method
comprising the steps of:

26

multiplexing (305) an information bit-stream
(315) and a placeholder bit-stream (320) to form a
multiplexed bit-stream (410);

receiving the multiplexed bit-stream;

replacing bits of said placeholder bit-stream
within the received multiplexed bit-stream with bits
derived from said information bit-stream within said
received multiplexed bit-stream to form a modified bit-
stream (450);

encoding the modified bit-stream to produce an
encoded bit-stream (125, 330, 460); and

transmitting the encoded bit-stream (152, 470).

12.   The method of claim 11, wherein the deriving
creates a new bit, but retains any bit from which
derivation has occurred (450).

13.   The method of claim 12, wherein the
replacing step comprises the steps of:

duplicating bits of said information bit-stream
within said received multiplexed bit-stream to form
duplicate bits; and

substituting the duplicate bits to replace bits
of said placeholder bit-stream within said received
multiplexed bit-stream (115, 450).

14.   The method of claim 11, further comprising
the steps of:

multiplexing an additional bit-stream (310) in
forming said multiplexed bit-stream; and

bypassing (420) said replacing step when operating on said additional bit-stream within said received multiplexed bit-stream to form said modified bit-stream (117, 450);

wherein said encoding step further comprises the steps of:

processing every bit of said modified bit-stream when operating on bits derived from said additional bit-stream; and

processing every other bit of said modified bit-stream when operating on bits derived from said information bit-stream (330, 460).

15. The method of claim 11, wherein the multiplexing step further comprises multiplexing an additional bit-stream (310) to form said multiplexed bit-stream.

16. The method of claim 15, wherein said multiplexing step comprises multiplexing a plurality of additional bit-streams, a plurality of information bit-streams, and a plurality of placeholder bit-streams to form said multiplexed bit-stream (410), each of said information bit-streams to be multiplexed by the multiplexer having an identical number of bits, each of said placeholder bit-streams to be multiplexed by the multiplexer having an identical number of bits, the multiplexing step being performed so as to multiplex each of the information and placeholder bit-streams for their respective identical number of bits before selecting another bit-stream for multiplexing (305).

17.   The method of claim 16, wherein said
multiplexing step is performed so as to select in
succession, over a predetermined number of bit-streams, no
more than three of said additional bit-streams (305).

18.   The method of claim 16 wherein the
multiplexing step multiplexes so as to input in succession
one or more of the additional bit-streams after each input
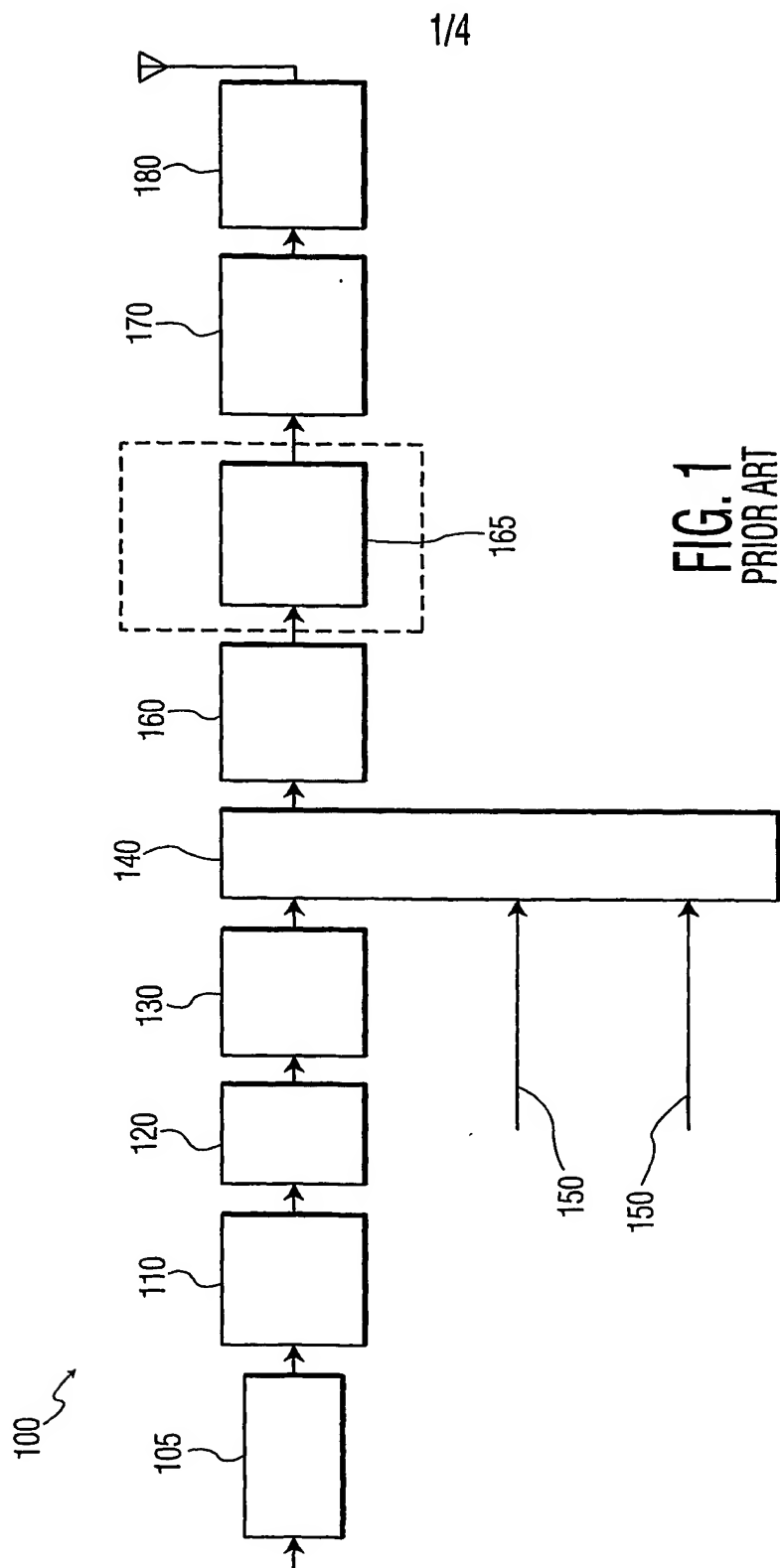of one of an information bit-stream and a placeholder bit-
stream (305).

19.   The method of claim 18, wherein the plural
bit-streams are identical in length, and the inputting of
one of an information bit-stream and a placeholder bit-
stream successively alternates, over at least most inputs
of the one information or placeholder bit-stream, between
an information bit-stream and a placeholder bit-stream
(305).

20.   The method of claim 11, wherein the
replacing step comprises the steps of:
          selecting bits from said information bit-stream
within said received multiplexed bit-stream;
          removing the selected bits from said information
bit-stream within said multiplexed bit-stream; and
          substituting the removed bits to replace bits of
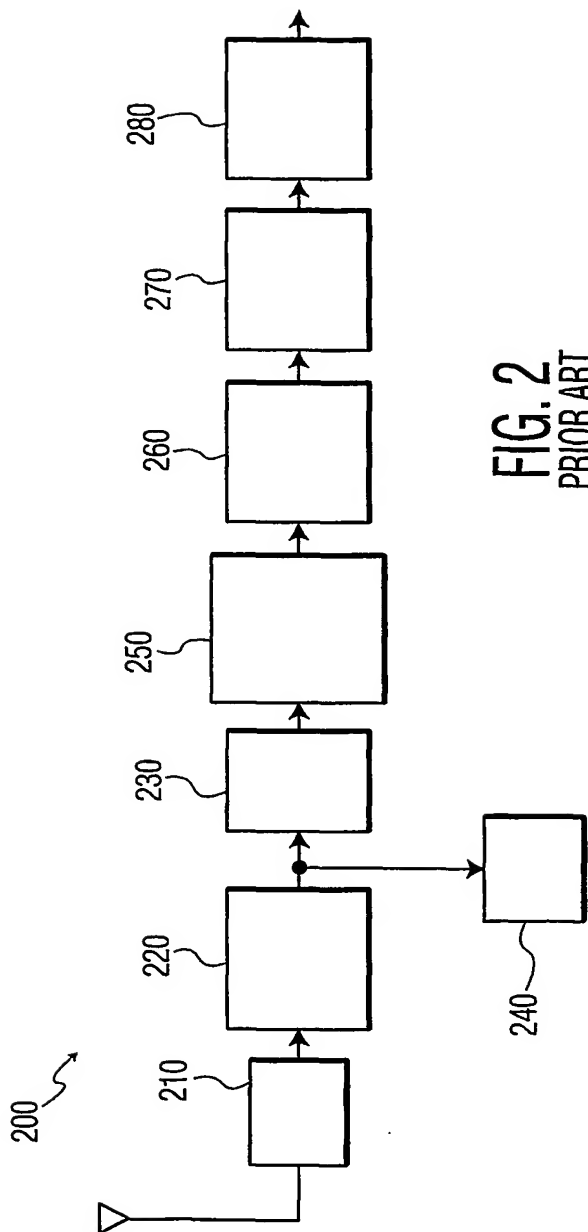said placeholder bit-stream within said received
multiplexed bit-stream (115, 405).

FIG. 1
PRIOR ART

FIG. 2
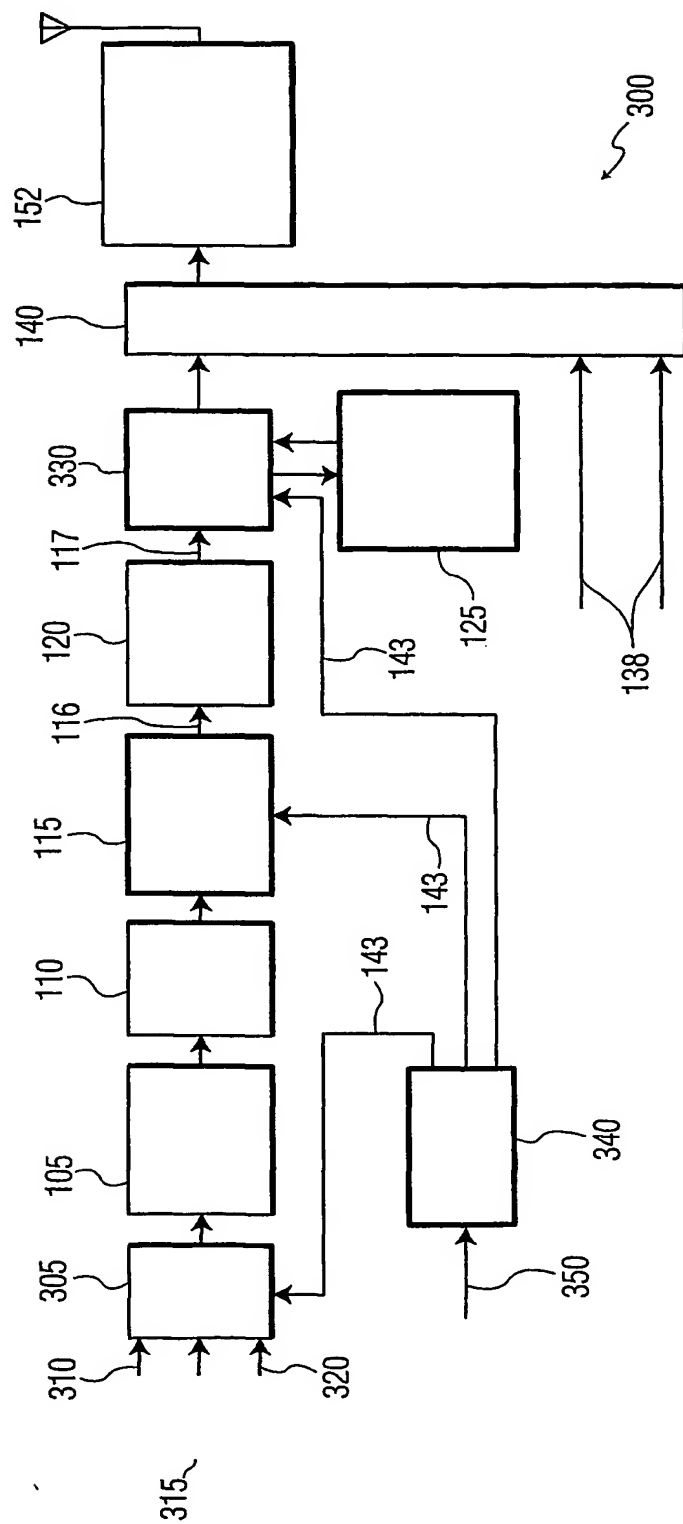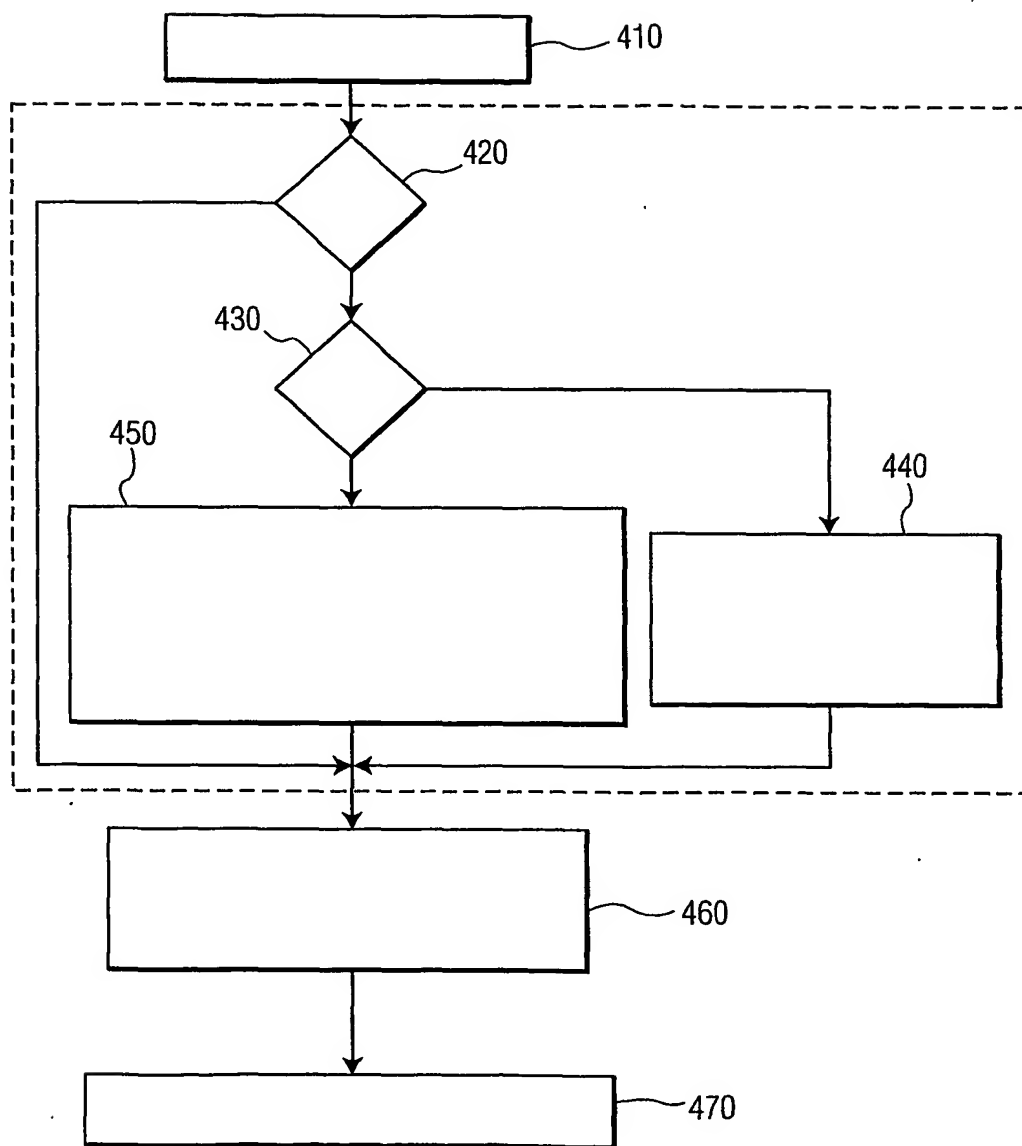PRIOR ART

3/4

FIG. 3

4/4

FIG. 4